Impacts of food and diets' life cycle: A brief review

IMPACTS OF FOOD AND DIETS' LIFE CYCLE: A BRIEF REVIEW

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Abstract

Recently, consumers are modifying their eating and consumption habits, especially due to healthy and ethical needs, followed by environmental concerns afterwards.

The aim of this study is to review the most recent findings about the impacts of different diets, assessed by means of the Life Cycle Thinking methodologies, and the possible implications of consuming more products of plant origin than an omnivorous diet. Many studies suggest that a lower consumption of meat and dairy products in favour of plant-based products reduce environmental and health impacts.

Some methodological and practical aspects should be improved by life cycle practitioners, when assessing the potential impacts of diets. In particular, more attention should be paid to the actual consumption patterns and the environmental damage factors linked to secondary services, such as the consumption of imported products, refrigerated or pre-cooked foods and/or use of single-portion packaged foodstuffs.

1. Introduction

The history of human nutrition has been marked by several factors that have influenced in a more or less significant way its distinctive characteristics. The availability of food has always been influenced by geographical and historical contexts, moral and religious issues, and exogenous factors such as wars and famines, affecting the access to food both in quantitative and qualitative terms.

In more recent years (from the middle of the 20th century), especially in advanced countries, other reasons have led man to change his eating habits, especially those of a healthy and ethical nature. This resulted in new nutrition patterns such as vegetarianism, veganism and other more or less widespread variants (Whorton, 1994).

The limitation of products of animal origin and their derivatives seems to be one of the most common choices for those who want to improve their health status. From a health point of view, meat and livestock products are often under accusation for the consequences that their excessive consumption has on obesity, heart disease and also in terms of carcinogenic risks. Recent reports from the International Agency for Research on Cancer (IARC) in Lyon, have defined red meat as probably carcinogenic (class 2A of the IARC classification) and processed red meat (sausages and salami) as definitely carcinogenic (class 1 of the IARC classification). All the data that resulted in this classification and the reflections on the subject are contained and described in detail in a monograph dedicated to "Red and processed meat", published by the IARC experts in 2018 and based on the review of more than 800 studies on the subject (airc.it).

From an ethical point of view, the slaughter of animals for consumption and their intensive use to obtain milk, cheese, eggs or other farm products is an important factor for those consumers more sensitive to animal welfare issues. The environmental issue also plays an important role in changing eating habits and today more than ever intensive livestock farming for meat and other products is considered to be one of the main causes of global warming, water pollution, loss of biodiversity and loss of soil and water resources. Furthermore, while the consumption of products of animal origin, such as milk and dairy products, can be considered acceptable in terms of animal welfare, these productions are often considered

more harmful than the production of meat, from an environmental point of view. In fact, to make some products such as cheese, a large quantity of milk is needed, amplifying the environmental impacts generated to produce it (Falcone et al., 2017). In recent years, public opinion has developed an "ecological" conscience about these issues, thanks to the environmental campaigns that have highlighted the phenomenon.

This problem, actually, also exists for other vegetable productions (e.g. vegetable oils), however their reduced consumption or the exclusion from consumption of some of them (e.g. palm oil) is enough to help reduce the effects on the environment.

The aim of this study is to review the most recent findings about the life cycle impacts of different diets and the possible implications of consuming more products of plant origin than an omnivorous diet.

2. Review Methodology

A brief systematic review has been conducted to evaluate the main contributions to the field of study, synthetizing the main concepts. The scientific literature has been reviewed according to predefined parameters (Tab 1) that allowed putting in evidence main results about the state of the art of the sustainability assessment of different diets. The scientific literature published from 2003 up to October 2019 was gathered by means of scientific databases (such as Scopus and Web of Science), as well as dedicated social networks and free on-line search engines; grey literature such as reports, unindexed conference proceedings and theses were discarded, and only the most recent (from 2017 onward) peer reviewed and indexed scientific literature was taken into account for the purposes of this review.

The search was conducted by means of specific terms in the fields “title”, “abstract” and “keywords” about life cycle tools (Life Cycle Assessment - LCA, Life Cycle Costing - LCC, Social LCA - SLCA, Life Cycle Sustainability Assessment - LCSA) and “diet”, “nutrition” and synonyms.

A grid has been constructed to gather all references in the rows, and to analyse all parameters in the columns. The grid system allowed to easily classify and compare the scientific contributions according to year of publication, source, typology of publication, typology of study, methodologies applied, goal and scope, scenarios compared, diets assessed, system boundaries, categories of impact assessed, and main results. Table 1 shows the grid parameters that allowed highlighting the common elements and divergent features.

Table 1- Grid elements

Parameters	*Characteristics and examples*
Authors, year, title, source	Identifications of the contributions
Typology of publication	Journal articles, Conference Proceedings, book chapters, reports, theses
Typology of study	Review, discussions papers, applicative studies, methodological proposals
Methodologies applied	LCA; LCC, SLCA, LCSA
Goal and scope	Main objectives of the assessment process

Scenarios	Objects of comparison
Diets under assessment	Vegan, vegetarian, omnivorous, etc.
System boundary	Boundaries considered in the evaluation
Indicators or categories of impacts	Human health, carbon footprint, ecotoxicity, land use, water consumption, climate change, etc.
Main results	Conclusions achieved

3. Results and discussions

The literature search resulted in 56 contributions published between 2003 and 2019, with a peak of publications in 2017 and 2018 (Fig. 1). As graphically shown in Fig. 2, the scientific literature (indexed sources, peer reviewed journals) are the most representative, corresponding to 63% journal articles.

For the purpose of this review, only scientific publications since 2017 have been taken into account, discarding grey literature such as reports, unindexed proceedings and theses.

Therefore, the final set of contributions analysed is composed by 18 papers, of which 16 are journal articles, one is an indexed conference proceeding, and one is a book chapter. The review grid with details of each paper is reported in Supplemental Material 1.

Fig. 1 Publications per year (all contributions)

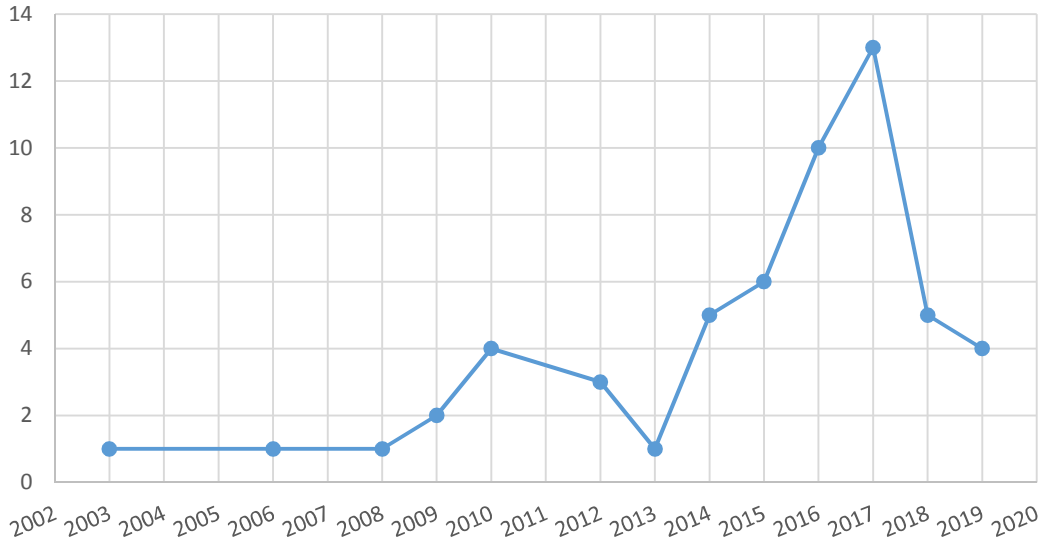
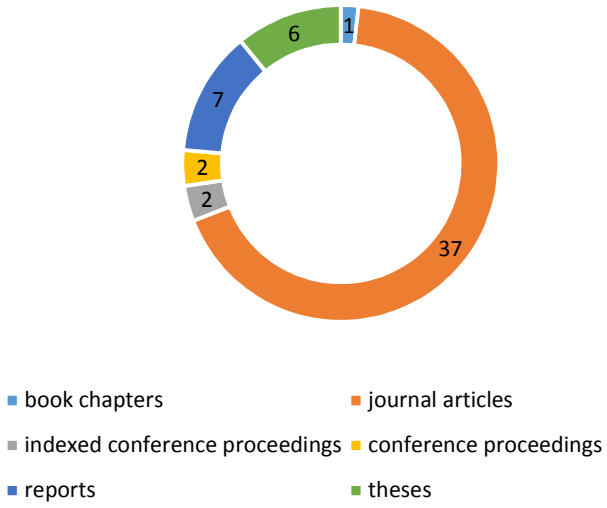


Fig. 2 Typologies of publications



Most of the papers gathered are applicative studies to assess the environmental impacts of dietary options by means of LCA, sometimes in combination with other methods, such as the ANOVA test and the Principal Component Analysis (Rosi et al., 2017), the environmental hourglass approach (Ulaszewska et al., 2017), the Nutrient-rich Dietary Index (Esteve-Llorens et al., 2019). No scientific contributions were found about the economic and social life cycle assessment of dietary options.

The most assessed impact category is Climate Change (all contributions), measuring the Global Warming Potential by quantifying the kg of CO_2-eq (kg of carbon dioxide-equivalent) of greenhouse gases emissions. Furthermore, 11 papers have deepened other environmental issues, such as water depletion (e.g. Goldstein et al., 2017; Notarnicola et al., 2017a; Rosi et al., 2017; Green et al., 2018) and land use (e.g. Chai et al., 2019; Tacaks, 2019; Blackstone et al., 2018).

As suggested by Notarnicola et al., (2017b) Life cycle Impact Assessment stage in food-related LCA studies should take into account all environmental impacts related to agricultural production such as loss of soil fertility, loss of soil structure, loss of pollinators, etc.

The common goal of the contribution reviewed were the comparison of the environmental performance between omnivorous, vegan and vegetarian diets (e.g. Choudhary and Kumar, 2017; Cleveland and Gee, 2017), categories to which most typologies of diets (e.g., Indian diet, Mediterranean diet, New Nordic Diet, US-style diet, Atlantic dietary pattern, Swedish food) could be associated (e.g. Ulaszewska et al., 2017; Martin and Brandão, 2017).

Indeed, several papers conclude that the biggest contributors to environmental impacts and damage are animal-based foods (meat and dairy products) (among others, Choudhary and Kumar, 2017; Notarnicola et al., 2017b; Chai et al., 2019); therefore, the presence of these types of products in the diets are the basic discriminants for environmental performances (Harwatt et al., 2017; Corrado et al., 2019).

Moreover, there is wide consensus, from a nutritional point of view, that plant-oriented dietary approaches are able to enhance human health, not only environmental performances. This typology of diets have been associated with reduced incidence of obesity, type 2 diabetes, cardiovascular disease, and has been showed to be a valid preventative strategy towards certain cancers (Joyce et al., 2012; Springman et al., 2016; Rosi et al., 2017; Lynch et al., 2018).

What has emerged so far could erroneously induce to hastily close any discussion on the environmental impact of different dietary styles. However, there are some methodological aspects, related to the determination of the environmental profile of diets through the LCA methodology, that can have a significant impact on studies' results.

For example, the choice of the Functional Unit (FU) is a critical element in the LCA studies (Notarnicola et al., 2017b) and can have a decisive influence on the results obtained. For example, there are wide differences if the FU is applied at the food level (kg of produces) or at the diet level (calories consumption) (e.g., Pernollet et al., 2017). Some authors use the FU at the food level but only to use then results to create consumption patterns comparable at the dietary level (Green et al., 2018; Corrado et al. 2019). This choice guarantees a great flexibility in the modelling of the different diets.

Another important element, undoubtedly, is the determination of the boundaries of the analysed system. Some studies limit the analyses at the food production phase or at its commercialization, thus neglecting an important part of the life cycle of the food and, therefore, underestimating the real impacts of this one (Pernollet et al., 2017). This is what emerges, for example, from the study by Corrado et al., (2019) in which, thanks to the analysis of the entire life cycle of foods up to their consumption, it emerged that domestic behaviours have a fundamental importance on the environmental impact of a diet. This can penalize the use of foods of vegetable origin because of the longer average cooking times and the need to ingest larger quantities of food to meet food needs. In this sense, the impacts generated in the production phase, which generally represent the largest contributor, weigh heavily (Esteve-Llorens et al., 2019).

Also the food production method plays a fundamental role, as emerges from the results of Martin and Brandão (2017) and Boone et al. (2019) that the use of organic products can further contribute to reducing impacts on GHG and potential toxicity but can increase impacts on eutrophication and soil loss. A detailed analysis from cradle to grave of all foods would help to better model different diets and plan multi-level mitigation strategies by acting on dietary patterns (Poore and Nemecek, 2018).

Reviewed articles were generally based on an analysis of different diets taking into account food production and diet modelling. Sometimes they analyse the cooking phase and waste related generally to consumption stage (e.g., Notarnicola et al., 2017a; Ulaszewska et al., 2017; Green et al., 2018; Corradi et al., 2019). A major weakness found is the exclusion from the analysis of real consumption patterns. Indeed, the typical consumer has to deal with several problems related to his/her diet.

The seasonality of fresh produces or the place where the consumer lives may entail restrictions on the availability of certain foods. Plant production in particular is closely linked to the geographical and climatic conditions in which it takes place. Modern production and distribution make possible to have almost all kind of foods available at any time of the year by importing them, store them for long periods or produce them by means of forcing, as protected crops; and this can have a significant negative impact on the environment (Cellura et al., 2012). Another problem with the large-scale adoption of a mainly plant-based diet may be that increased demand for certain products may cause problems with land use change. An example is that is occurring in Peru due to quinoa cultivation: the increasing demand could be a trigger for displacement, rebound and cascade effects, i.e. phenomena that are generally associated, among others, to land-use change, changes in farming practices, land degradation, depletion of genetic resources, pollution from increased use of pesticides and phytosanitary problems (Bedoya-Perales et al., 2018). In this sense the consequential approach of Life Cycle Assessment could be a suitable mean to evaluate all effects of a change.

Other factors that can significantly influence the impacts of a modern consumer's diet are the time and places he/she can dedicate to food processing, cooking and consumption. These two factors, in fact, often involve the use of packaged ready-to-go food, whether meat or vegetable, with a consequent increase in

the impacts associated to the production of packaging and its management as waste (Vignali, 2016). The problem of packaging is almost never addressed in the evaluation of different diets although it plays a crucial role.

The attention of research towards food-related problems led to the study of new products for human nutrition. Insects (Smetana et al., 2016), or even the creation in laboratory of surrogate products such as cultured meat (Mattik et al., 2015), seem to have very positive effects in mitigating environmental impacts related to human nutrition, in particular those relating to GHG emissions, Energy, Land and Water use (Tuomisto and de Mattos, 2011). Despite the positive nutritional and environmental results of consuming these new products, there are some barriers linked to production costs as well as to ethical, safety and disgust cocnerns (Fels-Klerx et al., 2018; Mancini et al., 2019).

4. Conclusions

The issue of environmental impacts related to dietary styles has gained considerable interest, in particular thanks to consumers' growing awareness of issues related to modern pattern of food production and consumption, especially livestock and dairy productions, considered among the principal causes of global warming, soil and water consumption. The studies produced in the last years on the assessment of environmental impacts related to food consumption behaviours leave no doubt that a lower consumption of meat, processed meat and dairy products in favour of vegan and vegetarian diets contributes positively in reducing the greenhouse gases effects, as well as in terms of land use and water depletion. However, it has emerged that many aspects need to be taken into account when assessing the life cycle of a diet; in particular aspects related to real consumption patterns that often introduce environmental damage factors linked to secondary services. The development of alternative foods could provide additional mitigation tools to meet consumer needs, but further research is needed.

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Impact can vary 50-fold among producers of the same product, creating substantial mitigation opportunities. However, mitigation is complicated by trade-offs, multiple ways for producers to achieve low impacts, and interactions throughout the supply chain. Producers have limits on how far they can reduce impacts. Most strikingly, impacts of the lowest-impact animal products typically exceed those of vegetable substitutes, providing new evidence for the

importance of dietary change. Cumulatively, our findings support an approach where producers monitor their own impacts, flexibly meet environmental targets by choosing from multiple practices, and communicate their impacts to consumers

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